

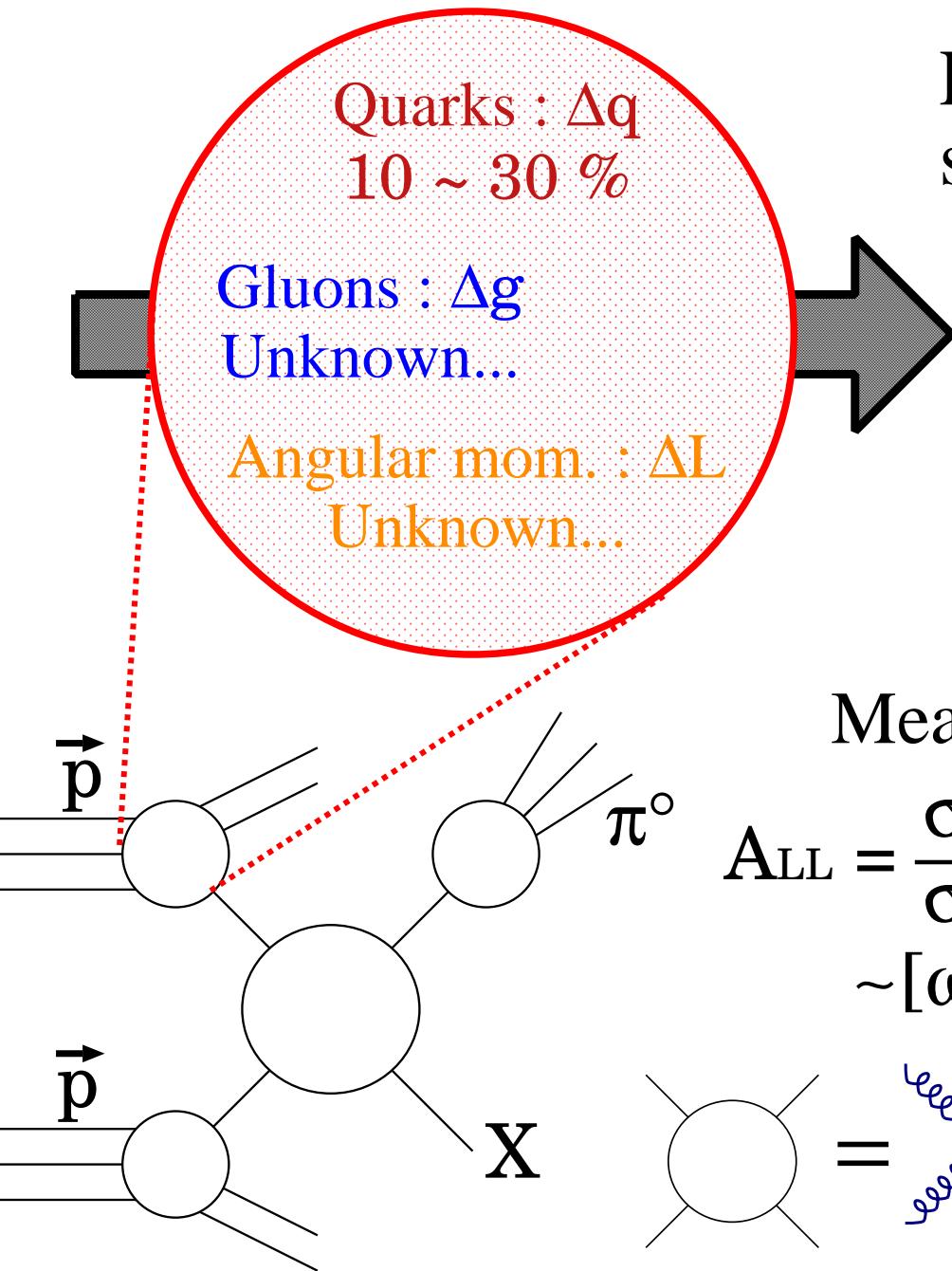
Probing gluon polarization with π° 's in longitudinally polarized proton collisions at the RHIC-PHENIX experiment.

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for the PHENIX Collaboration

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Motivation of π° ALL Measurement for Δg



Proton structure, especially spin structure, is still unknown.

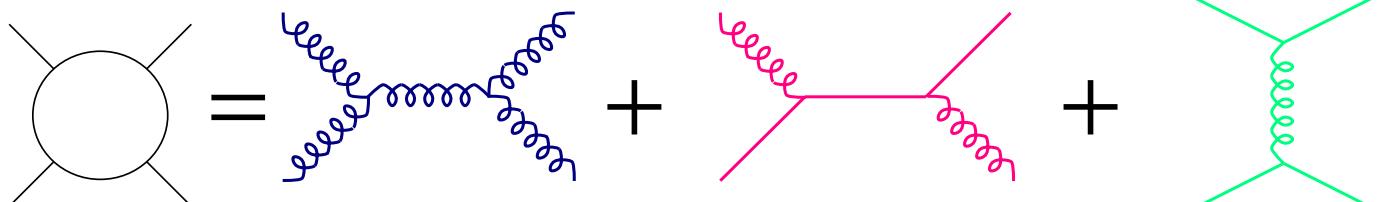


Shine a light on
the gluon polarization Δg

Measure ALL in $\vec{p} \vec{p} \rightarrow \pi^\circ$ production.

$$A_{\text{ALL}} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

$$\sim [\omega_{gg}] (\Delta g)^2 + [\omega_{gq} \Delta q] (\Delta g) + [\omega_{qq} (\Delta q)^2]$$



How to calculate ALL

1. Calculate $\text{ALL}(\pi^\circ + \text{BG1})$ and $\text{ALL}(\text{BG2})$ independently.

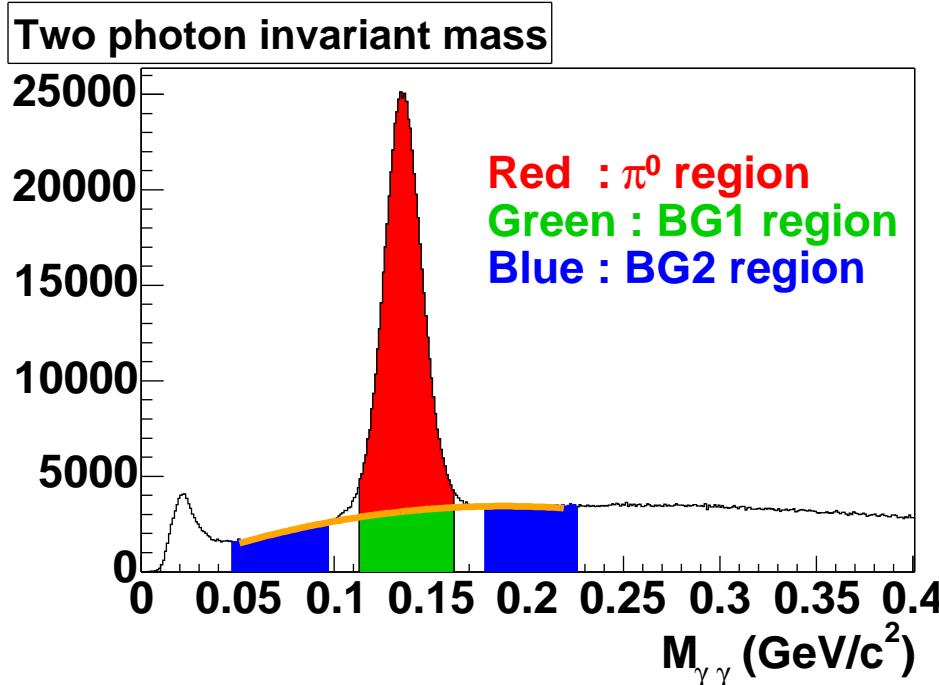
$$\text{ALL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P \cdot P} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}} \quad R = \frac{L_{++}}{L_{+-}}$$

2. Fit π° peak to obtain fluctuation of π° .

$$w_{\pi^\circ} = \pi^\circ / (\pi^\circ + \text{BG1}). \quad (w_{\text{BG}} = 1 - w_{\pi^\circ})$$

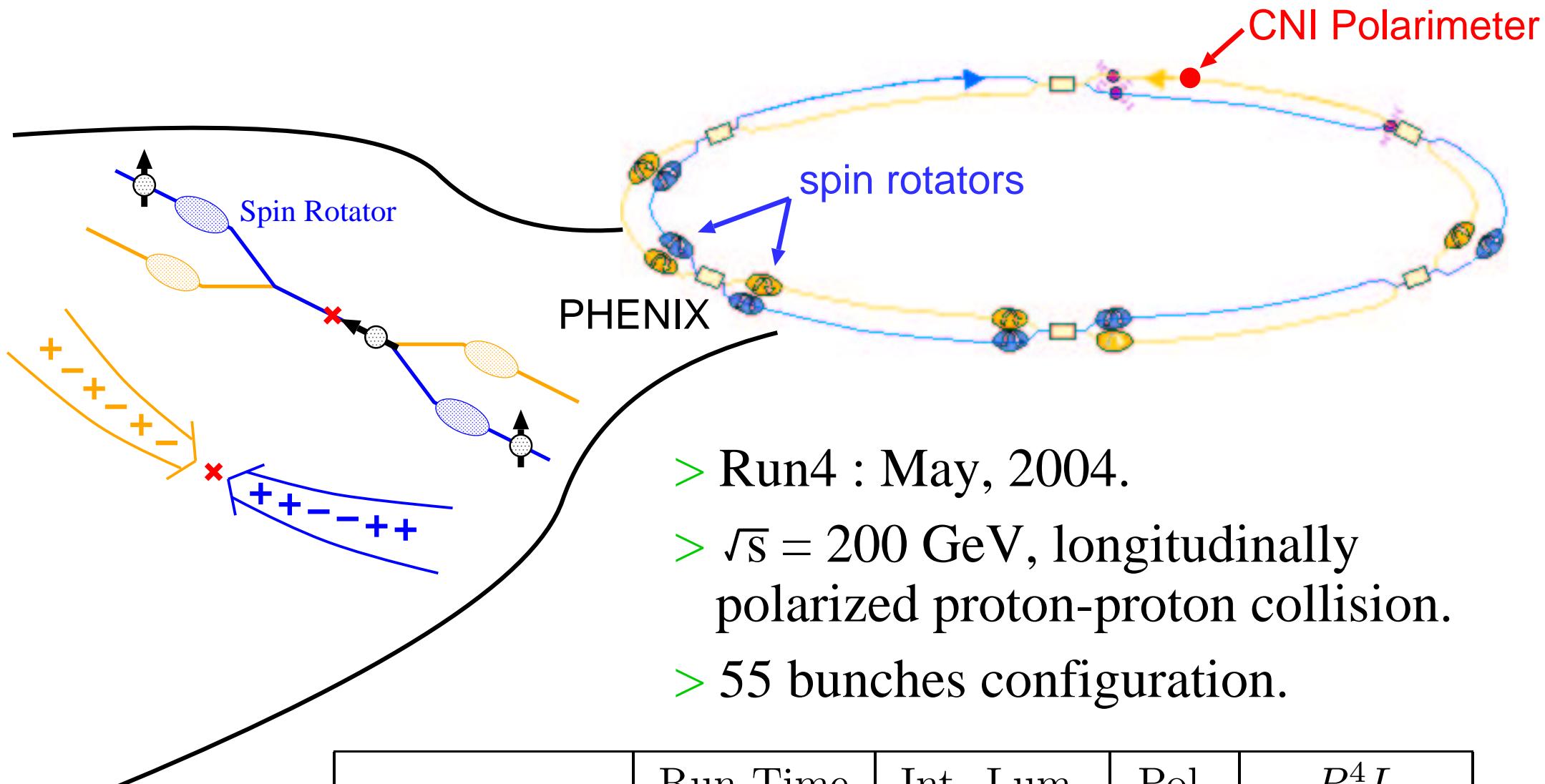
3. Subtract $\text{ALL}(\text{BG2})$ from $\text{ALL}(\pi^\circ + \text{BG1})$ and get $\text{ALL}(\pi^\circ)$.

$$\text{ALL}(\pi^\circ + \text{BG1}) = w_{\pi^\circ} \cdot \text{ALL}(\pi^\circ) + w_{\text{BG}} \cdot \text{ALL}(\text{BG2})$$



p_T (GeV/c)	π^0 stat. (w_{BG})
1-2	1151k (31%)
2-3	510k (13%)
3-4	91k (7%)
4-5	17k (5%)

RHIC (Relativistic Heavy Ion Collider)

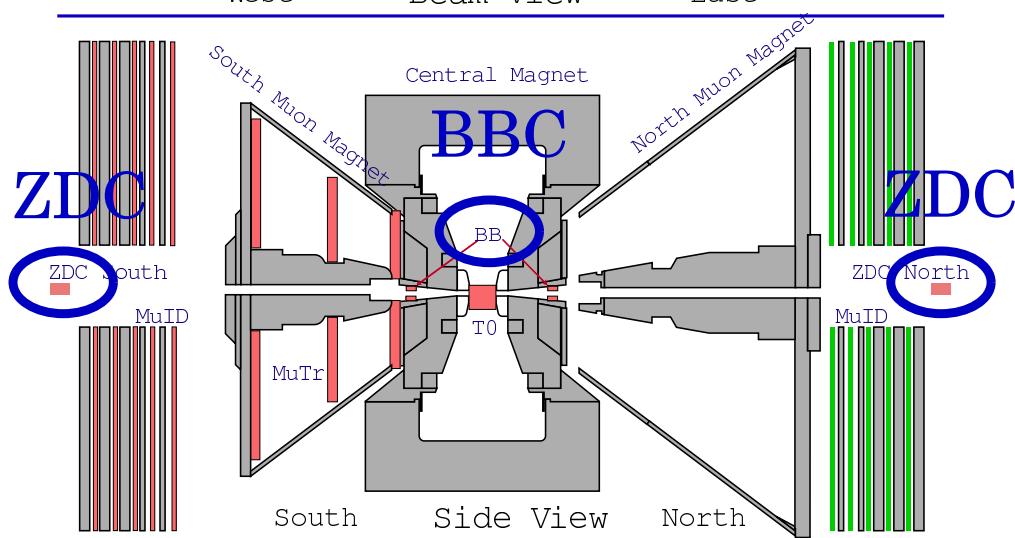
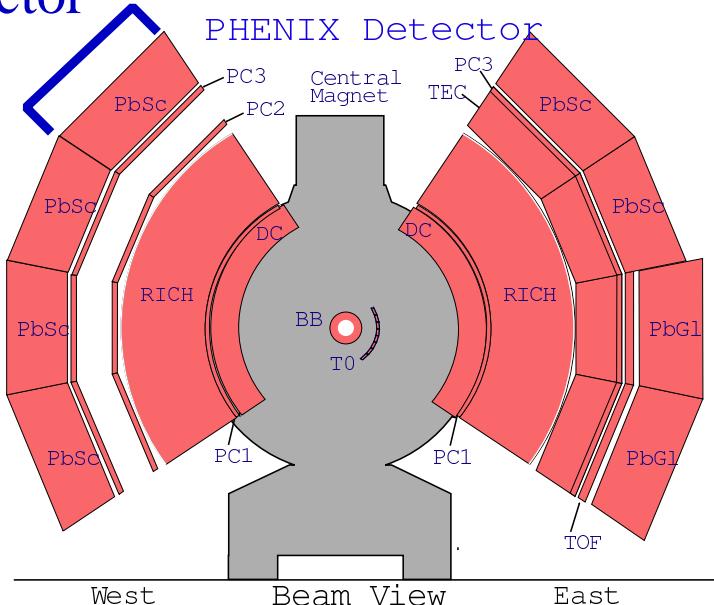


	Run Time	Int. Lum.	Pol.	$P^4 L$
Run 3 (2003)	4 weeks	220 nb^{-1}	27%	1.17 nb^{-1}
Run 4 (2004)	4 days	75 nb^{-1}	40%	1.92 nb^{-1}

PHENIX detector

EMCal

1 sector



Electromagnetic Calorimeter (EMCal)

- > Measure photon energy and position. ($\pi^0 \rightarrow \gamma\gamma$)
- > Acceptance
5m far from collision point.
 $|\eta| < 0.35$, $\phi : 90+90$ degree.
- > PbSc(6 sectors) and PbGl(2 sectors).
Fine segmented. ($\Delta\eta \cong \Delta\phi \cong 0.01$)
- > Energy resolution
 $\text{PbSc} : 8.1\%/\sqrt{E(\text{GeV})} \oplus 2.1\%$
 $\text{PbGl} : 5.9\%/\sqrt{E(\text{GeV})} \oplus 0.8\%$
- > Position resolution
 $\text{PbSc} : 5.7\text{mm}/\sqrt{E(\text{GeV})} \oplus 1.6\text{mm}$
 $\text{PbGl} : 8.4\text{mm}/\sqrt{E(\text{GeV})} \oplus 0.2\text{mm}$

Beam-Beam Counter (BBC)

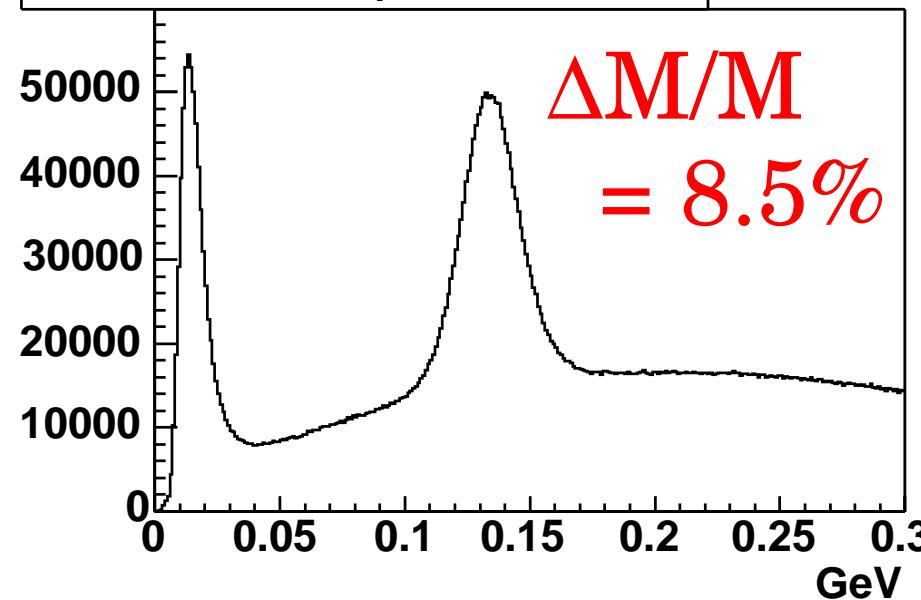
- > Used for relative luminosity measurement.
- > Acceptance : $3.0 < \eta < 3.9$

Zero Degree Calorimeter (ZDC)

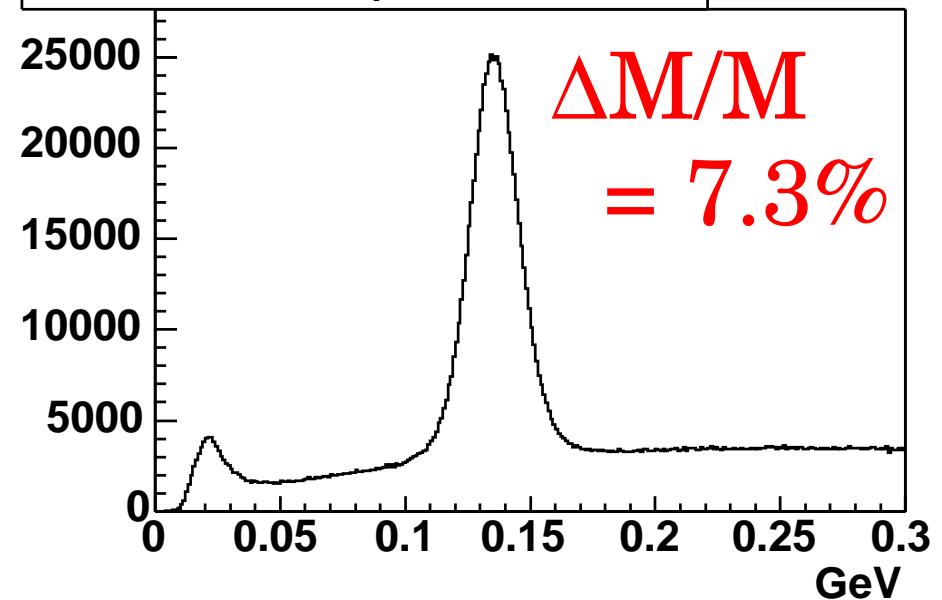
- > Used for relative luminosity measurement.
- > Acceptance : ± 2 mrad

π° mass spectrum

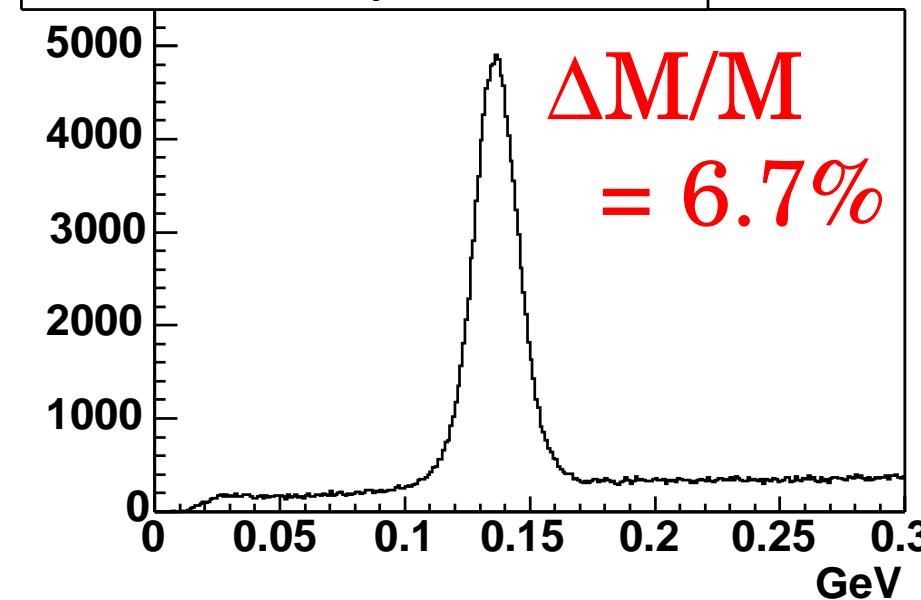
$1.0 \text{ GeV}/c < p_T < 2.0 \text{ GeV}/c$



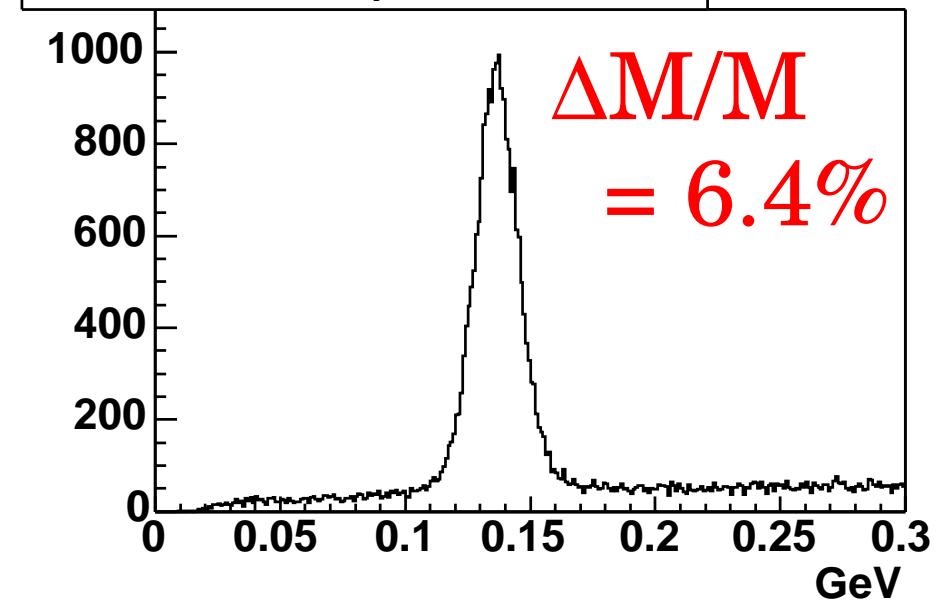
$2.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



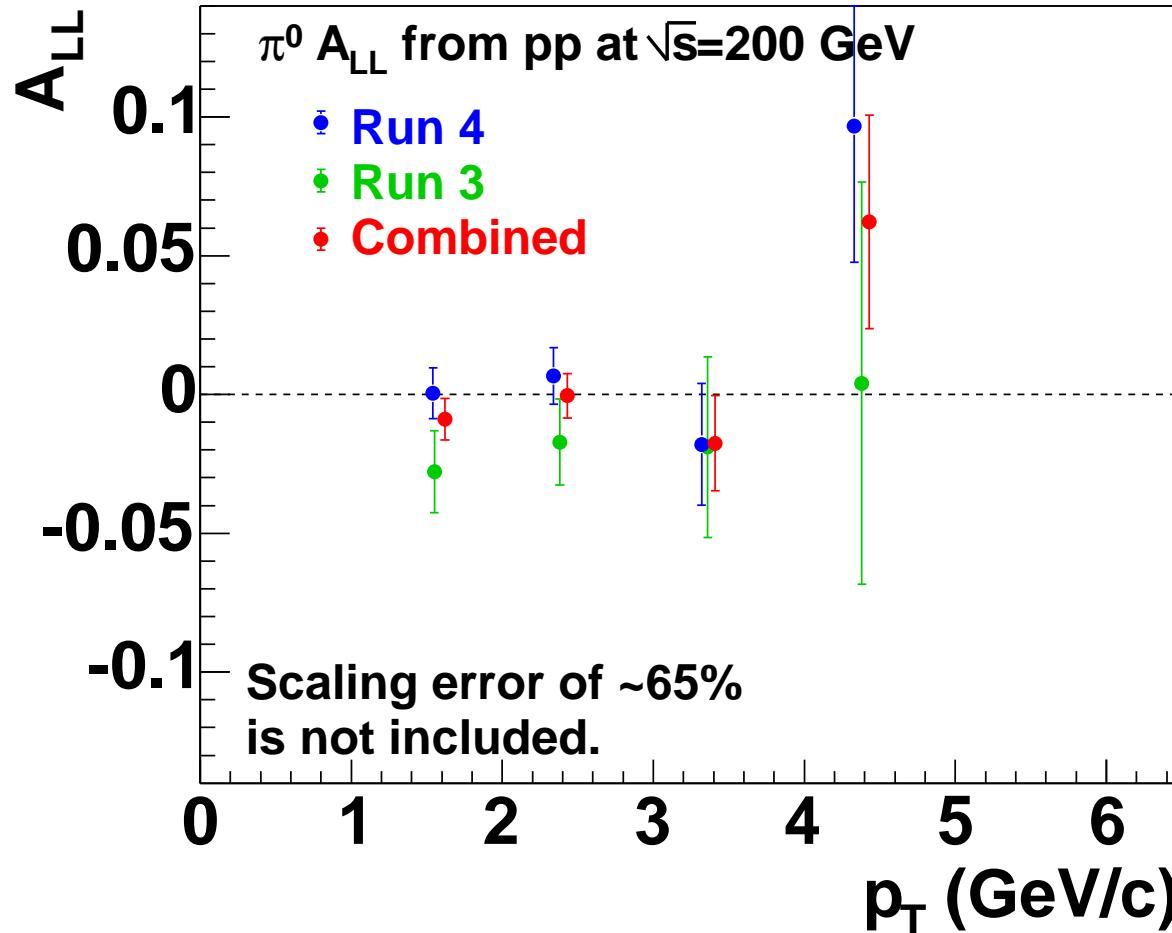
$3.0 \text{ GeV}/c < p_T < 4.0 \text{ GeV}/c$



$4.0 \text{ GeV}/c < p_T < 5.0 \text{ GeV}/c$



All results

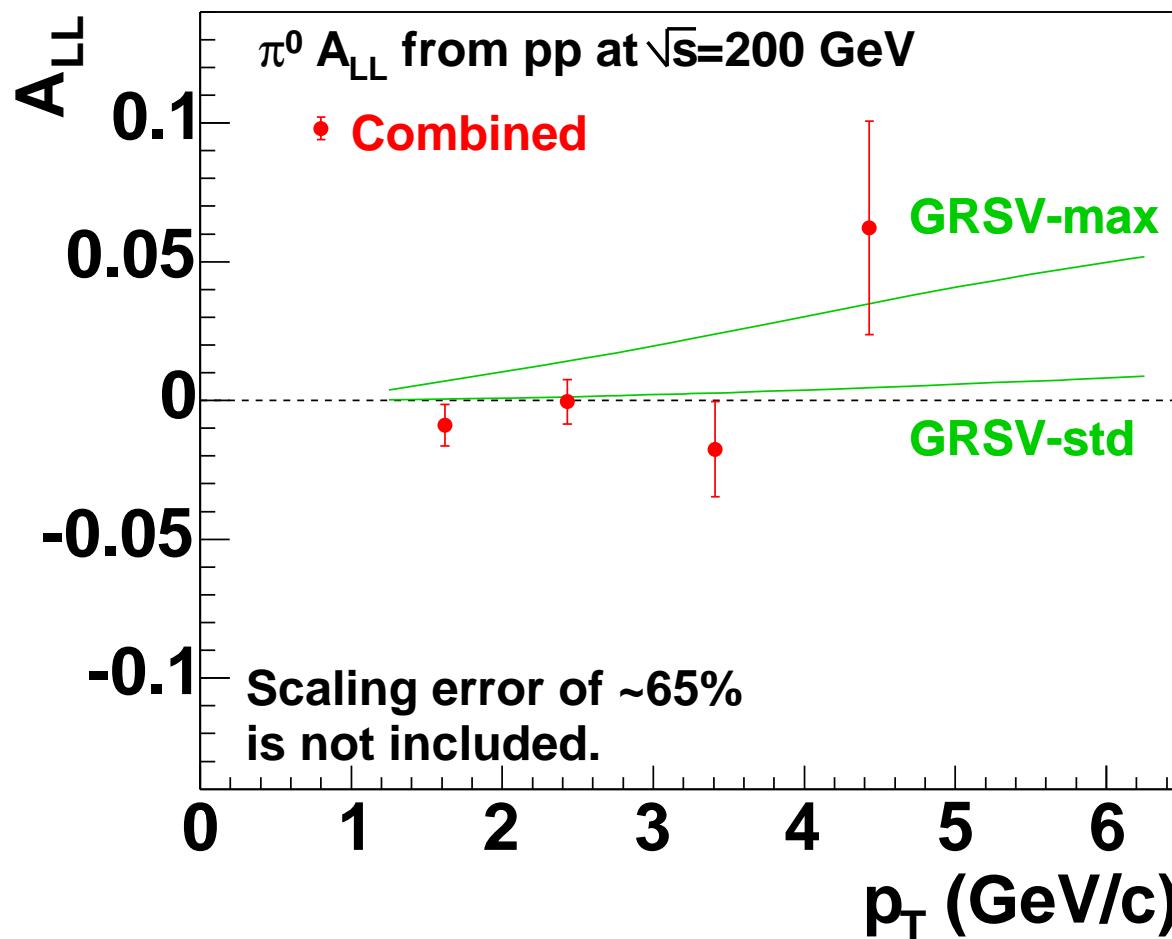


Chi-square test to check consistency between Run-3 and Run-4.
 $\longrightarrow \chi^2/NDF = 5.7 / 4$

Figure of merit
 Run-3 : 1.17
 Run-4 : 1.92
 \longrightarrow All uncertainty become smaller.

p_T (GeV/c)	$A_{LL}^{\pi^0}$ (Run 4) (%)	$A_{LL}^{\pi^0}$ (Run 3) (%)	$A_{LL}^{\pi^0}$ comb. (%)
1-2	0.0 ± 0.9	-2.7 ± 1.3	-0.9 ± 0.7
2-3	0.7 ± 1.0	-1.3 ± 1.3	0.0 ± 0.8
3-4	-1.8 ± 2.2	-1.7 ± 2.8	-1.8 ± 1.7
4-5	9.7 ± 4.9	0.7 ± 6.2	6.2 ± 3.8

Comparison with theory



GRSV-std :
 $\int \Delta g dx = 0.7$ at $Q = 2.2$ GeV

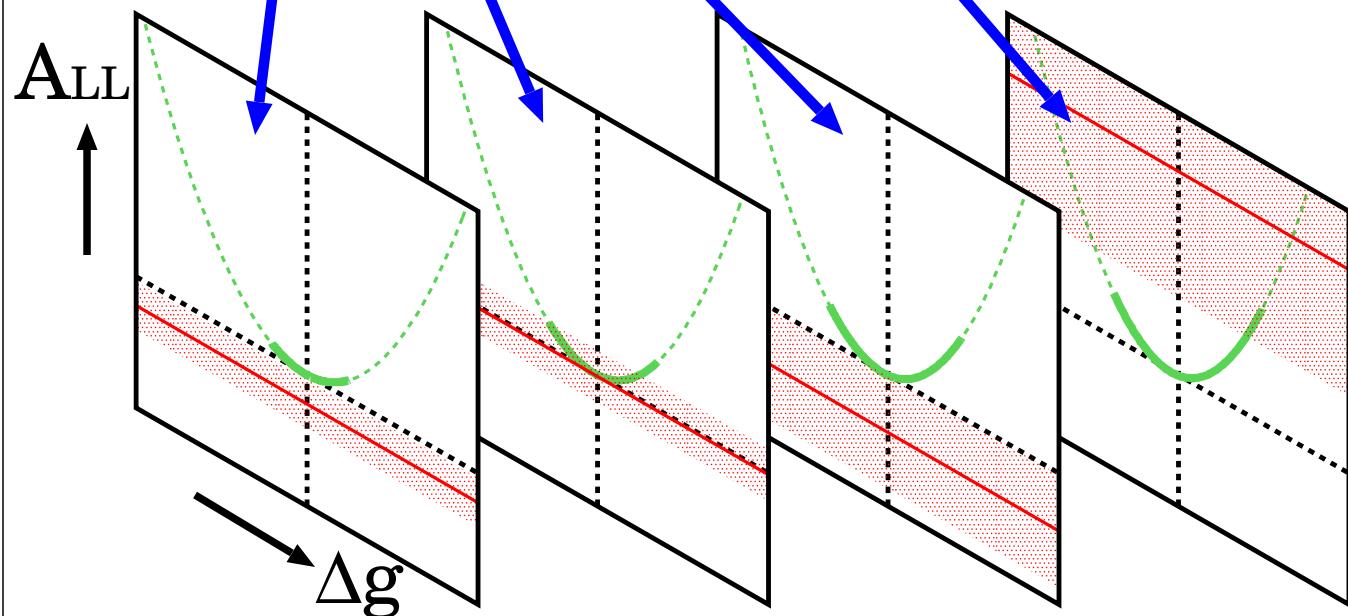
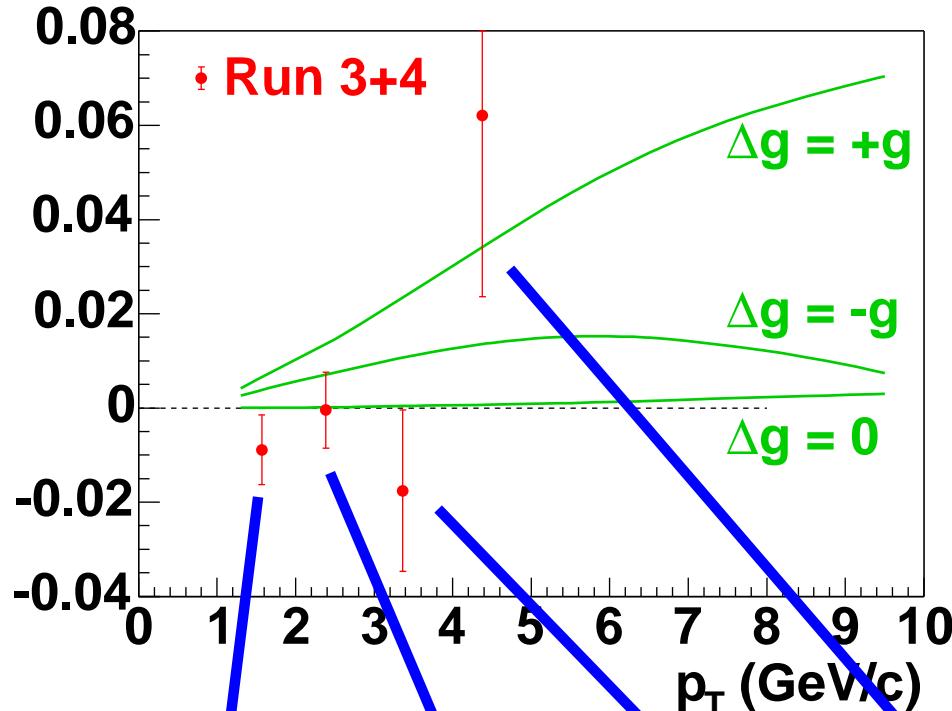
GRSV-max :
 $\Delta g(x) = g(x)$ at the input scale.

Confidence level between theory and Run-3 & Run-4 combined data shows measurement supports GRSV-std model.
(B. Jager et.al., Phys. Rev. D67, 054005 (2003))

	GRSV-std	GRSV-max
4 points (1-5 GeV/c)	21-24%	0.00-6%
3 points (2-5 GeV/c)	27-29%	0.01-13%

We got Δg ?

$\pi^0 A_{LL}$



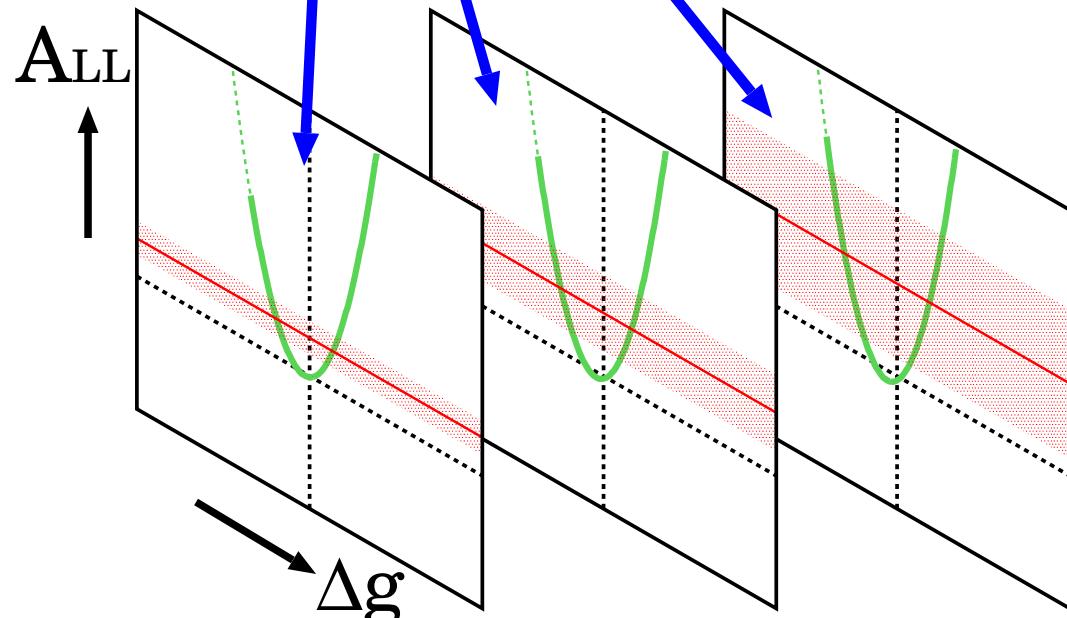
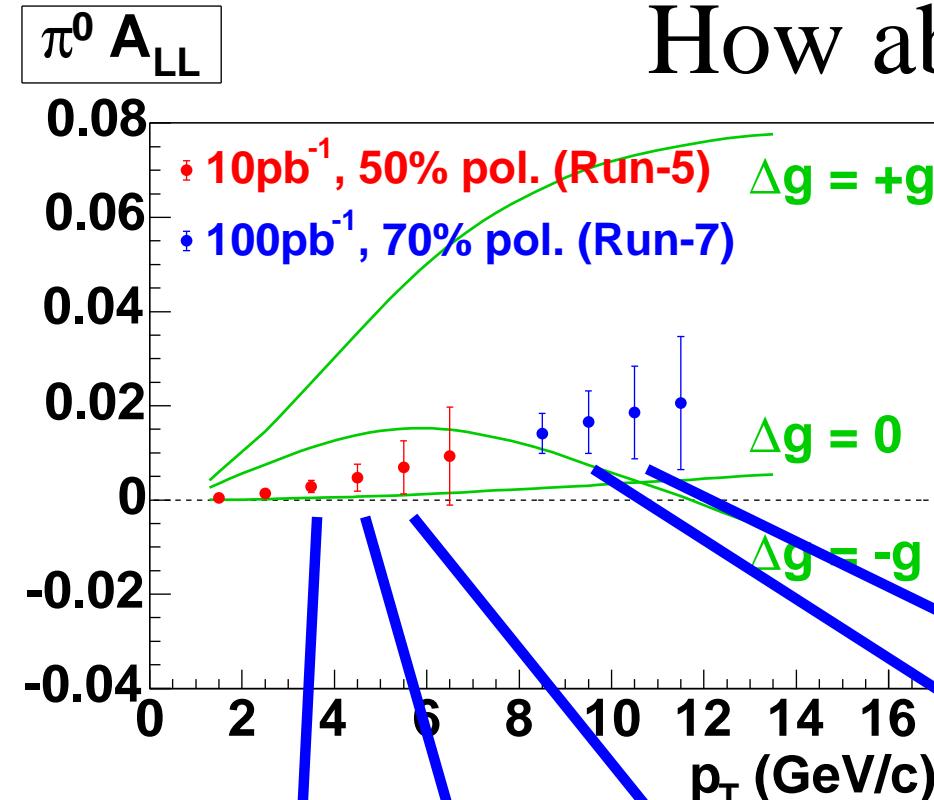
$$A_{LL} \sim a(\Delta g)^2 + b(\Delta g) + c$$

A_{LL} is calculated when
 $\Delta g(x) = +g(x)$, $-g(x)$ and 0
at the input scale, $Q = 0.4$ GeV.
(W. Vogelsang, hep-ph/0405069)

Relation of Δg and $\pi^0 A_{LL}$ is
determined in this rough model.

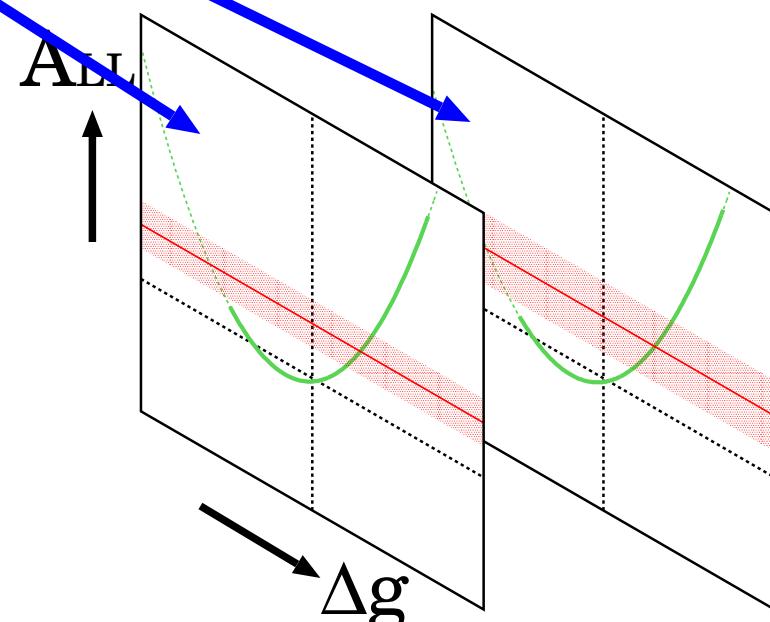
Possible Δg corresponds
to the region green curve
and red band crossing.

How about Run-5 ?



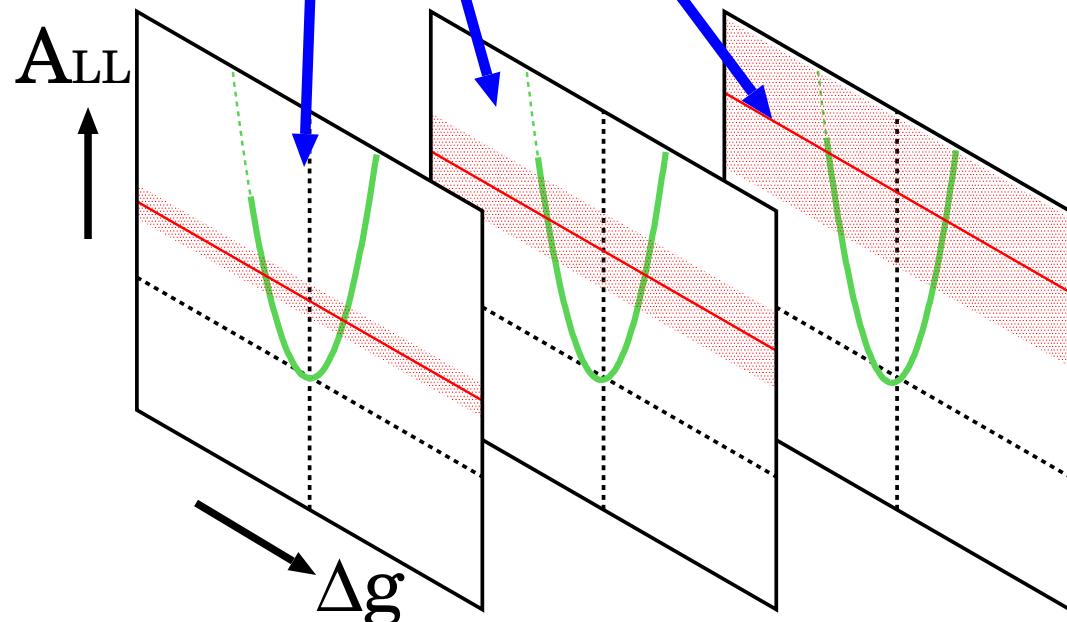
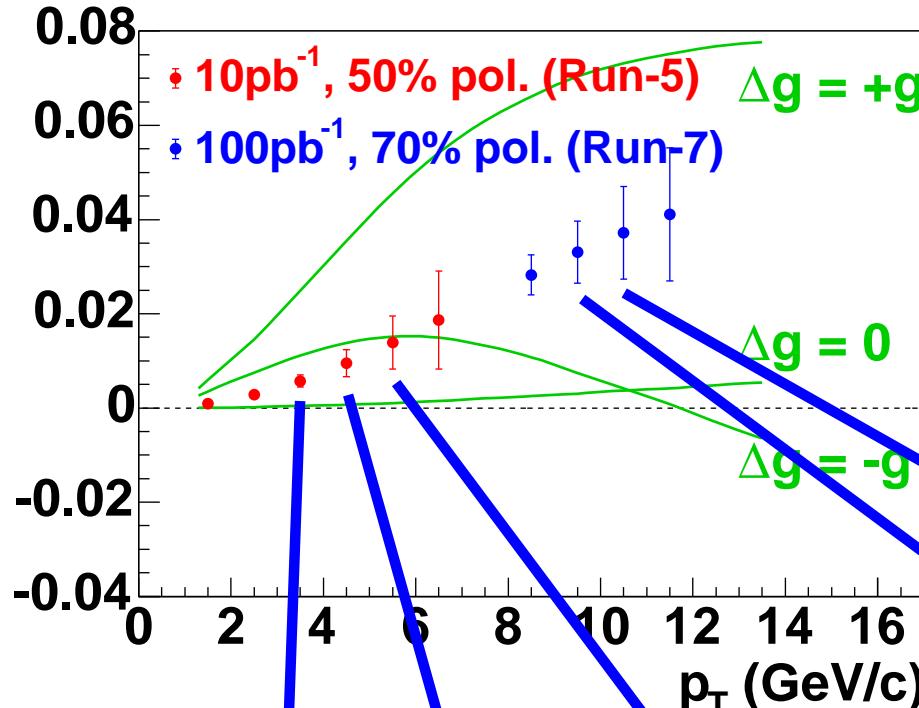
Center of points is in case of GRSV-std.

We will get further constraints on Δg in Run 5.



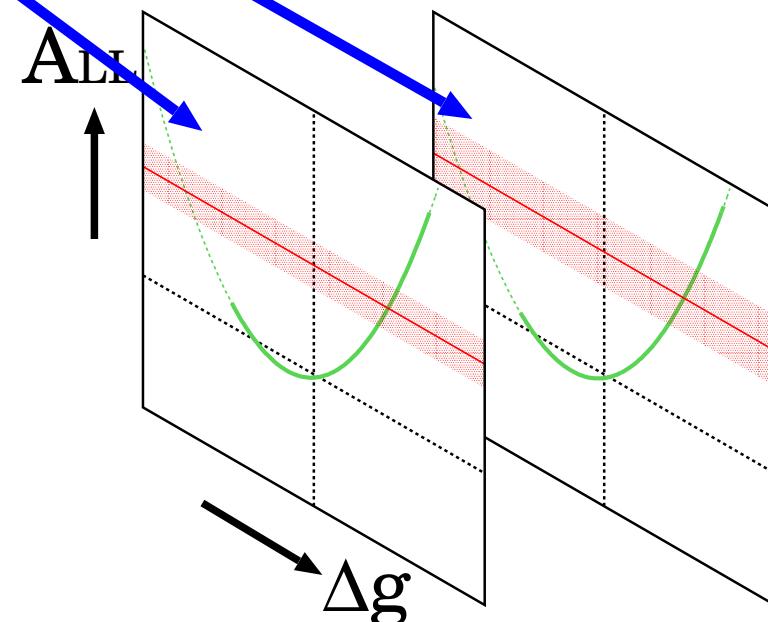
$\pi^0 A_{LL}$

How about Run-5 ?



Center of points is in case of GRSV-std x 2.

We will get further constraints on Δg in Run 5.



Summary

We measured $\pi^0 A_{LL}$ in polarized pp collisions at RHIC at May 2004.

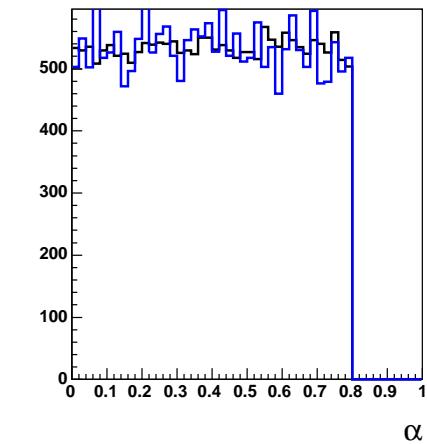
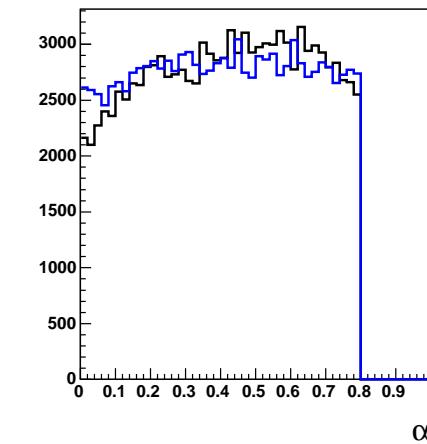
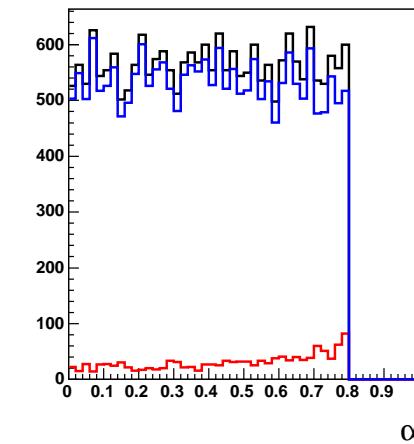
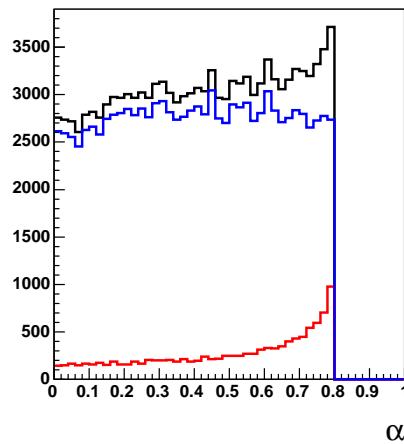
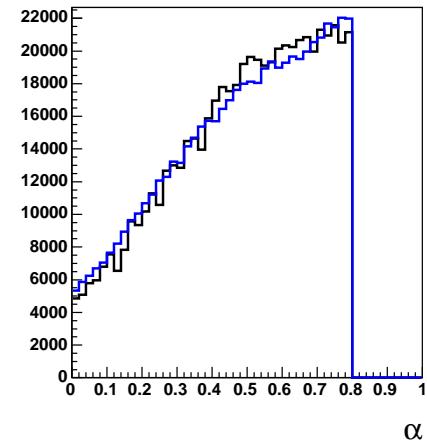
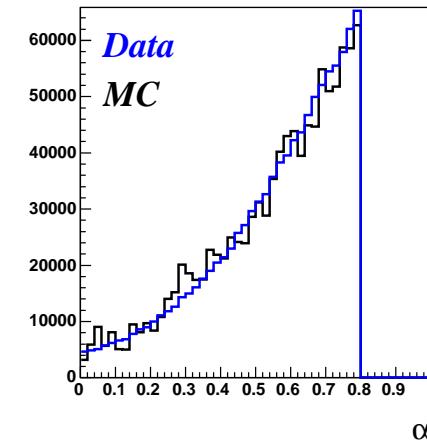
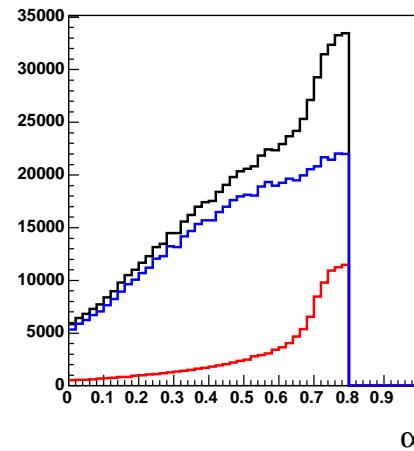
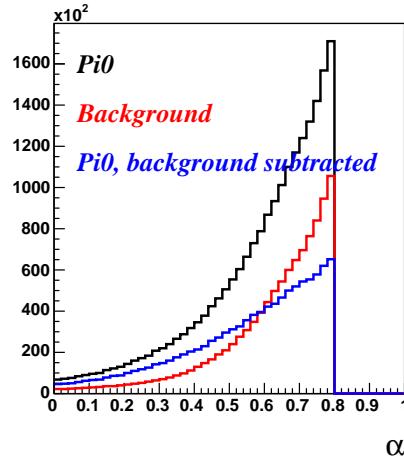
$\sqrt{s} = 200 \text{ GeV}$, $1 < p_T < 5 \text{ GeV/c}$, $|\eta| < 0.35$.

Though data size in Run-4 is about 1/3 of last year, uncertainty of A_{LL} become smaller due to higher beam polarization. In this different experimental condition, the results of Run-4 is consistent with Run-3 within error.

p_T (GeV/c)	$A_{LL}^{\pi^0}$ (Run 4) (%)	$A_{LL}^{\pi^0}$ (Run 3) (%)	$A_{LL}^{\pi^0}$ comb. (%)
1-2	0.0 ± 0.9	-2.7 ± 1.3	-0.9 ± 0.7
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3-4	-1.8 ± 2.2	-1.7 ± 2.8	-1.8 ± 1.7
4-5	9.7 ± 4.9	0.7 ± 6.2	6.2 ± 3.8

In coming Run-5 from this winter, more precise measurement will be done and it is expected to obtain further constrains on Δg by $\pi^0 A_{LL}$.

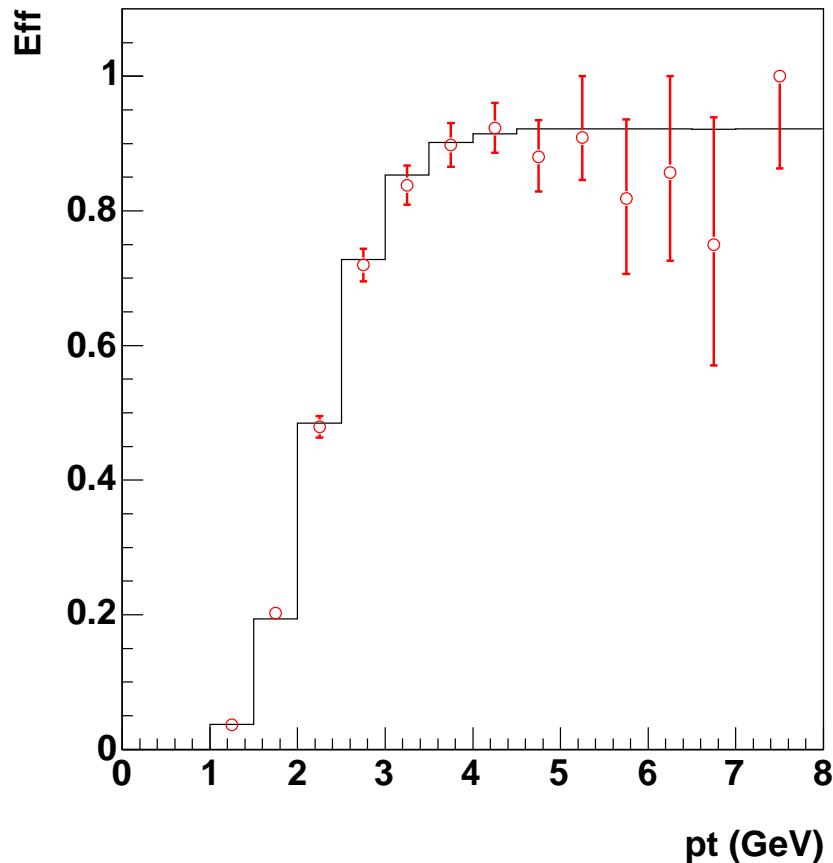
Energy asymmetry (α) comparison between MC simulation and data.



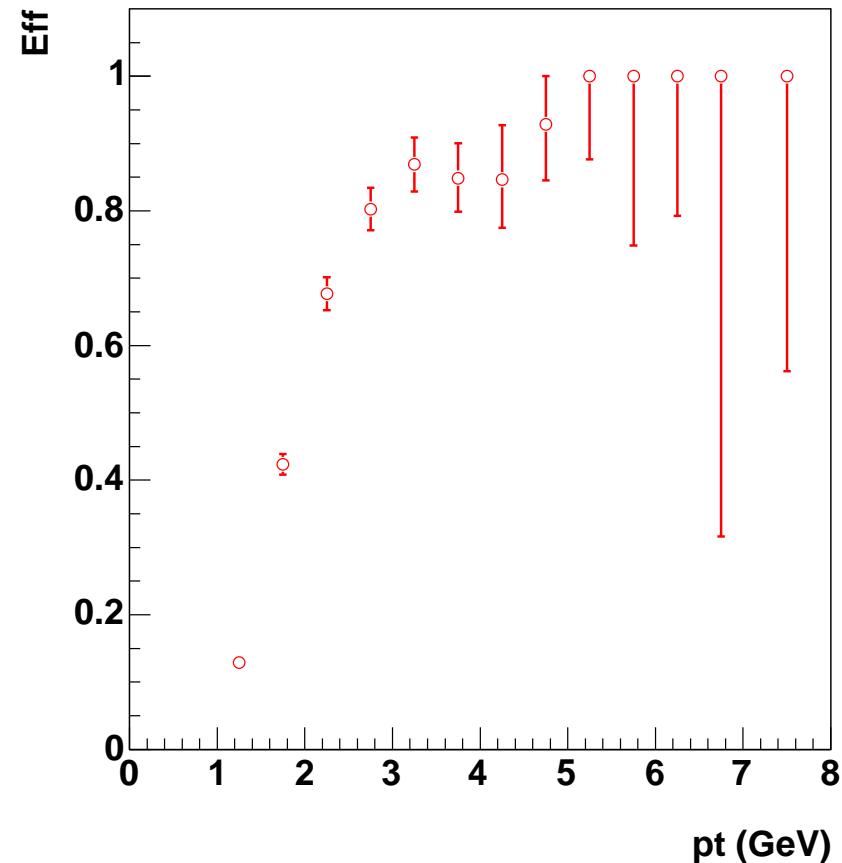
- > MC simulation matches real data well.
- > α of BG region reproduce a of BG under the π^0 peak.

Gamma3 Trigger Efficiency

PbSc efficiency



PbGl efficiency



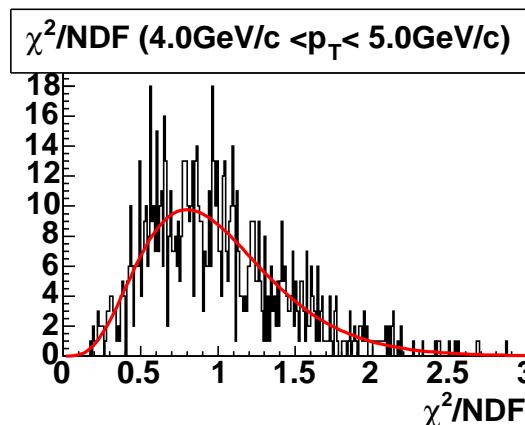
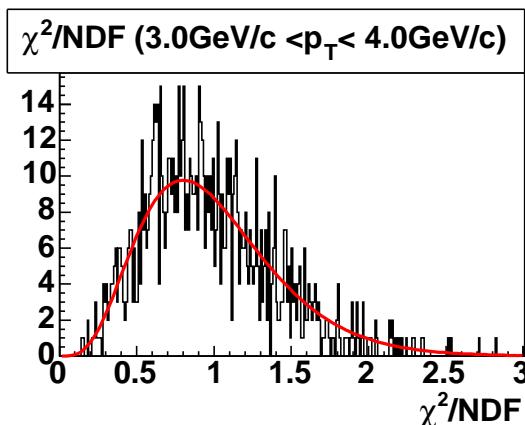
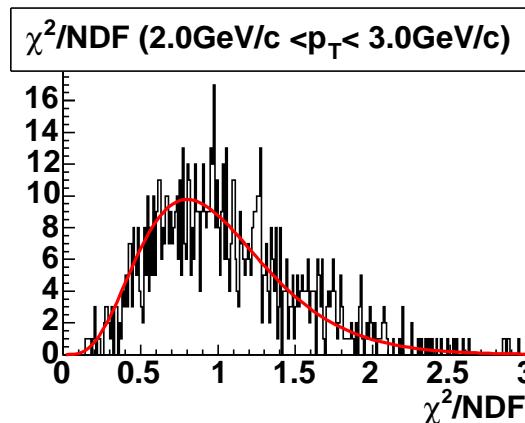
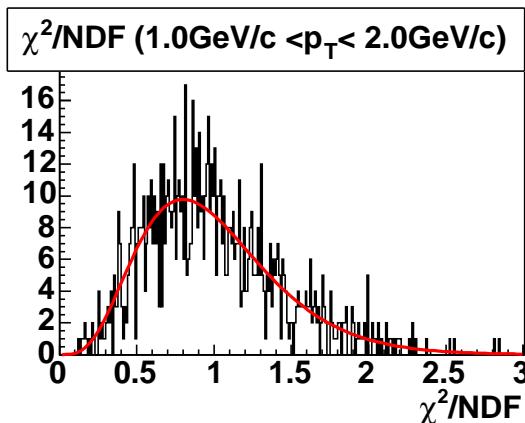
p_T (GeV/c)	1-2	2-3	3-4	4-5
Efficiency	7%	54%	86%	90%

p_T (GeV/c)	1-2	2-3	3-4	4-5
Efficiency	20%	71%	86%	90%

Systematic error from bunch shuffling

Bunch shuffle :

Randomly assigns helicity for each crossing.
Check chi-square from fitting fill vs. All.



Reduced chi-square distribution from bunch shuffling has good agreement with statistically expected curve.
(All non-correlated syst. error are negligible compared to stat. errors)

How to measure ALL

$$A_{\text{LL}} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P \cdot P} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}} \quad R = \frac{L_{++}}{L_{+-}}$$

P : Beam Polarization

R : Relative Luminosity

$N_{++(+-)}$: Yield with same(opposite) helicity

Measurement consists of 3 part.

1. P : Beam polarization

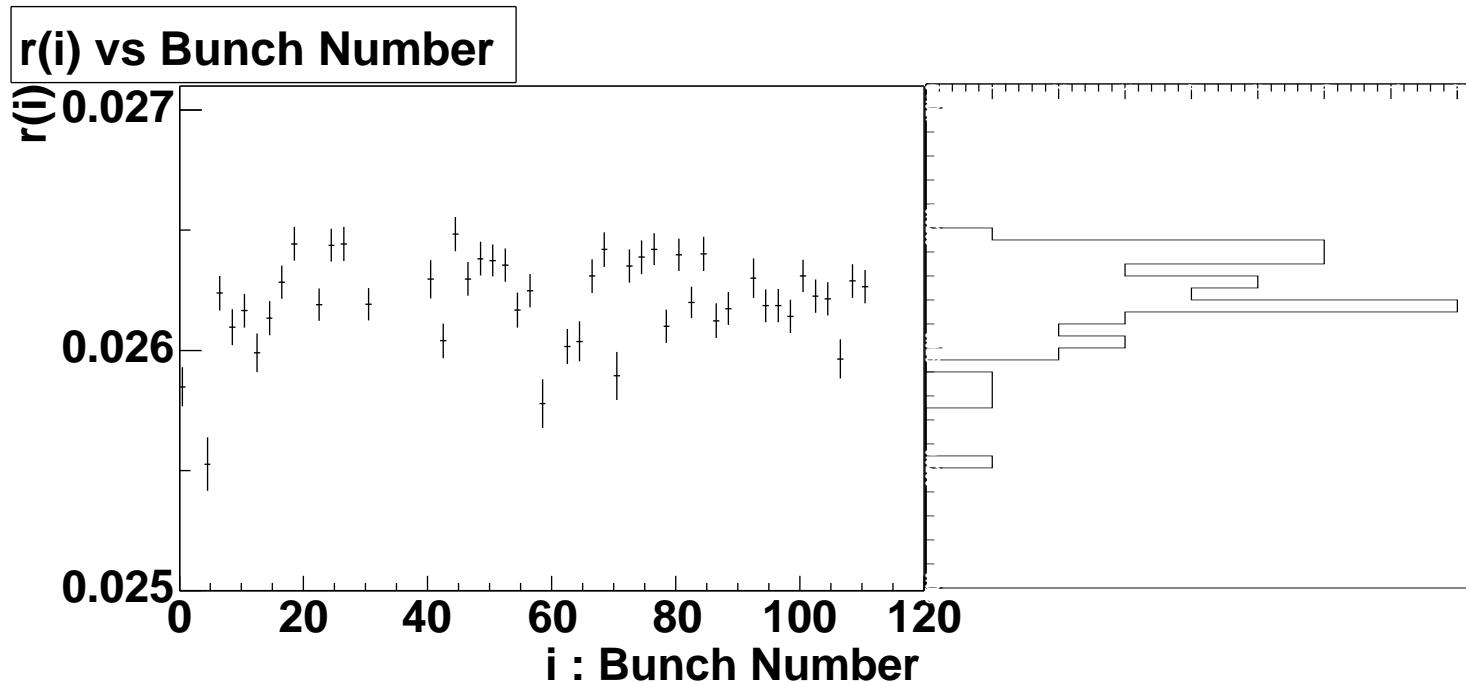
(CNI polarimeter, PHENIX Local polarimeter)

2. R : Relative luminosity (BBC and ZDC)

3. N : π° detection (EMCal)

Relative Luminosity

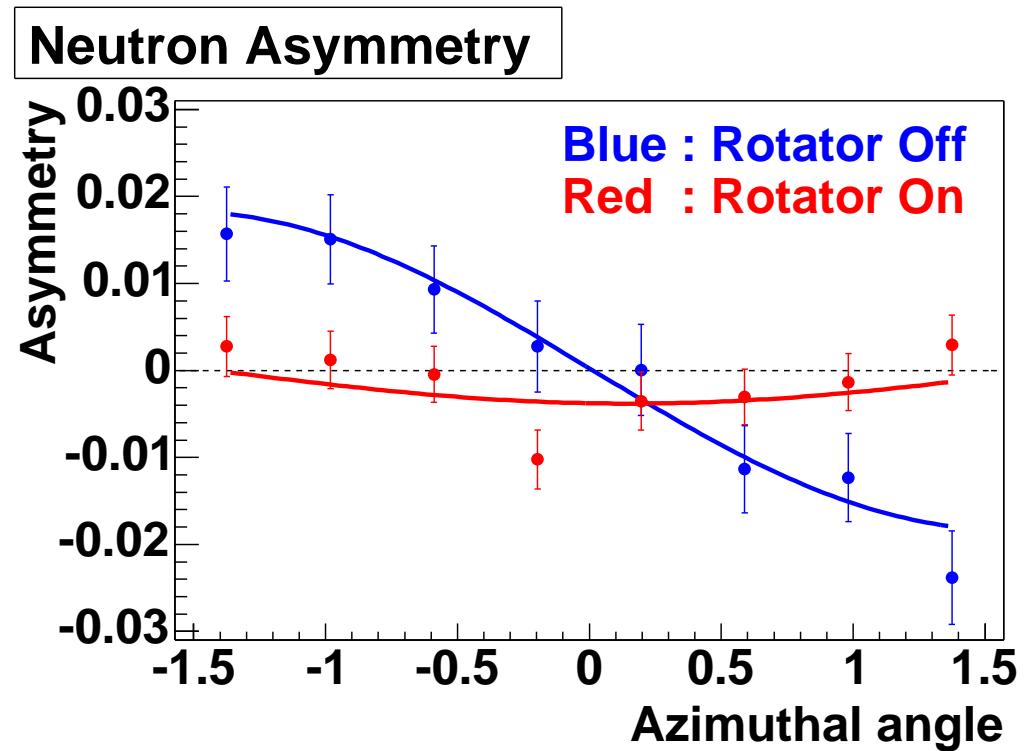
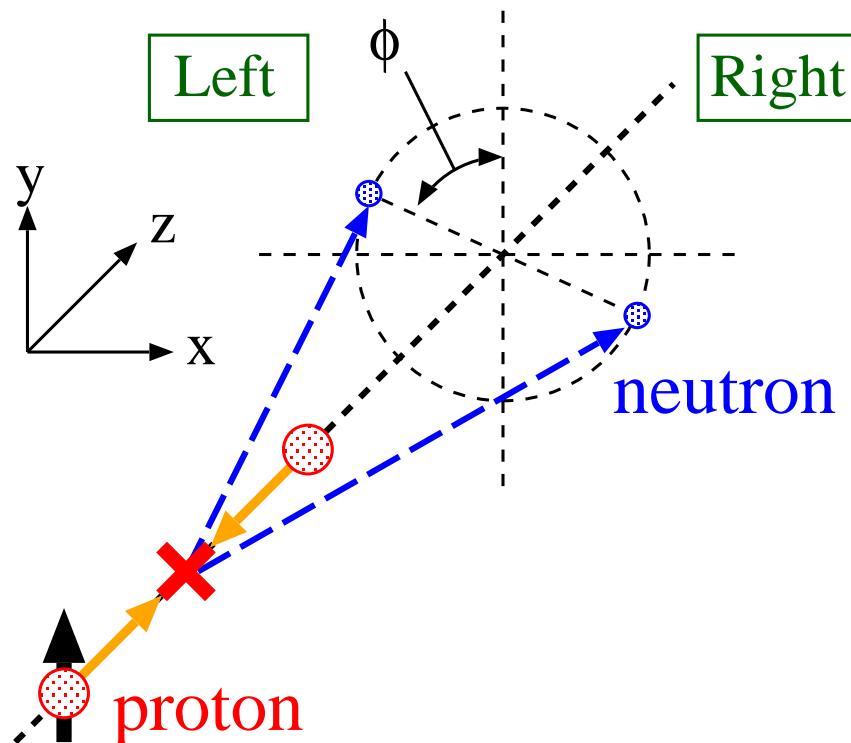
- > Number of event measured by BBC is used as R.L.
- > $r(i) = \frac{N_{ZDC}(i)}{N_{BBC}(i)}$ should be constant. (i : bunch number)



$\Delta R = 5.8 \times 10^{-4} \rightarrow \Delta A_{LL} = 1.8 \times 10^{-3}$ (in 40% polarization)
is achieved.

Longitudinal component of beam polarization

Longitudinal component of beam polarization is obtained by measuring single transverse spin asymmetry of neutrons.



$$\langle P_L/P \rangle_{\text{blue}} = 99.68^{+0.21 + 0.13}_{-0.65 - 0.0}$$

$$\langle P_L/P \rangle_{\text{yellow}} = 99.82^{+0.16 + 0.0}_{-0.75 - 0.0}$$

x_g region by PHENIX + π° ALL

